Recent Issues: GENIE + Geant4

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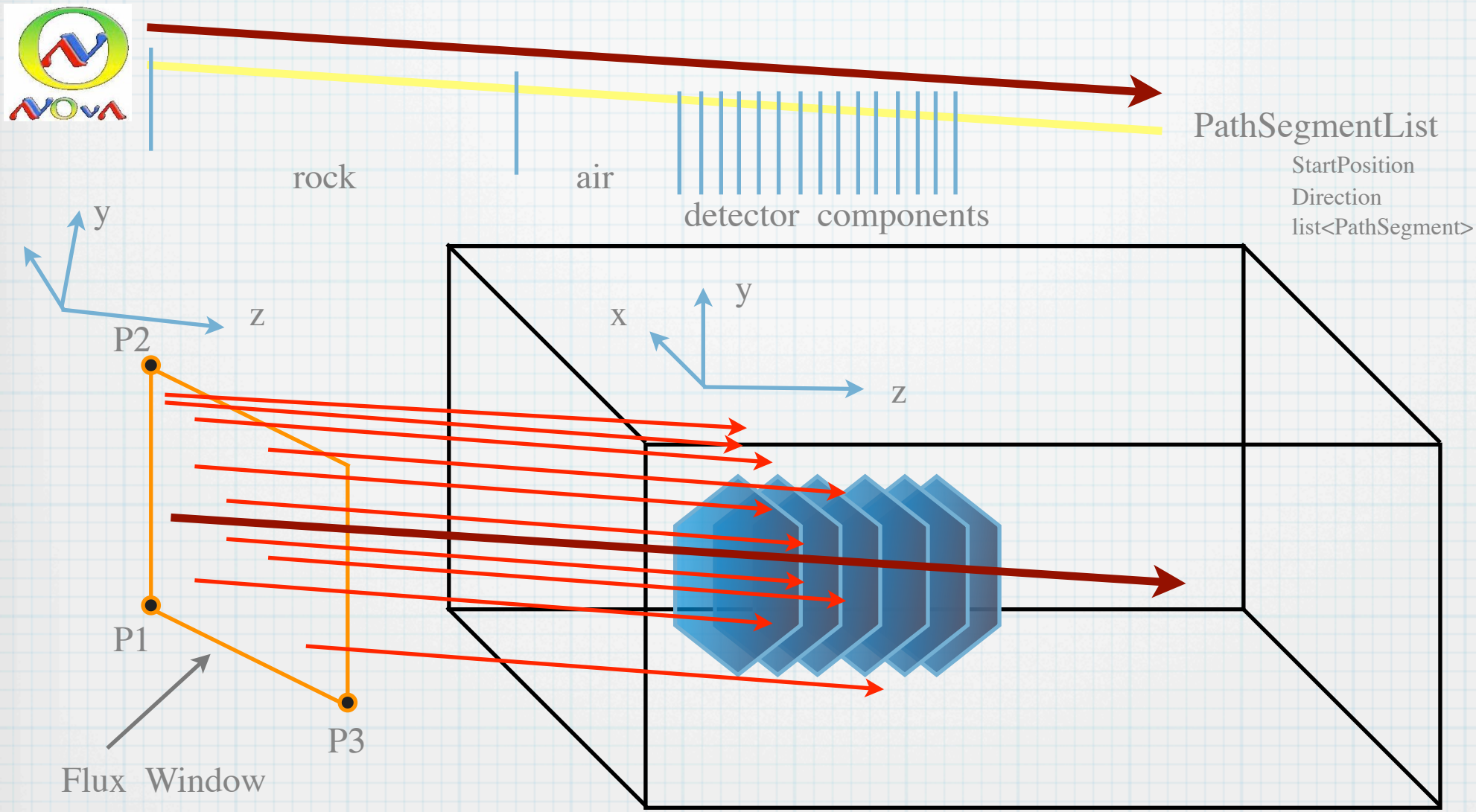
Where the vertices are

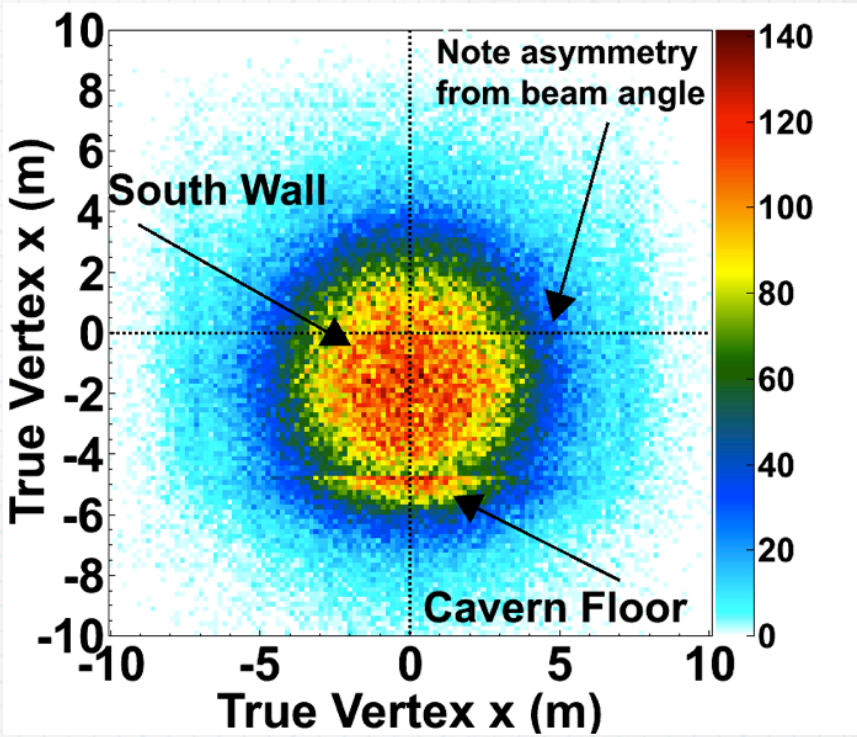
- GENIE runs ν rays through the geometry, taking note of volume boundary crossings
  - only considers those contained in the “top volume”
  - for NOvA this is normally “vDetEnclosure”
- Vertex is chosen (if at all) along the set of path segments weighted by length, material type & density, x-section
- Post-swimming trimming of path segment list provides a means of imposing a fidicual volume
  - can not expand what wasn’t “seen” (i.e. top volume)

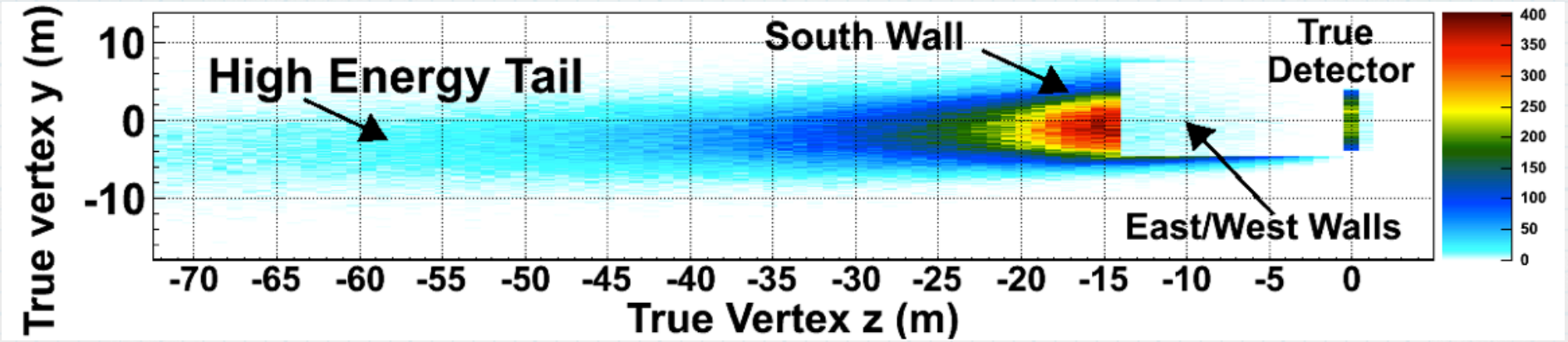
G*Flux + ROOTGeomAnalyzer



Where the MINOS Vertices Are

- Illustrative pictures from Matt Strait (MINOS-6643)
- These are the origin of reconstructed MC particles that enter the front face of the FarDet
- In the FarDet the beam points 3° up (in contrast to down in the NearDet)
- dE/dx ~ 4.2 MeV/cm in the rock
  - 1 GeV μ ~ 2.5m

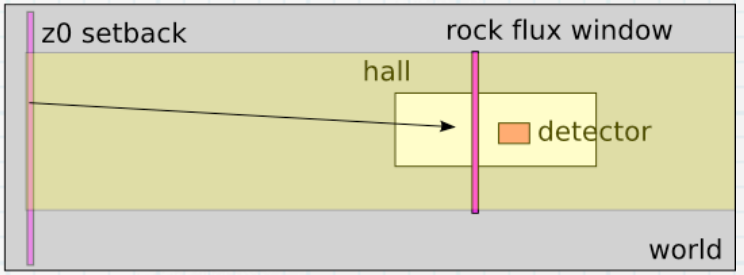




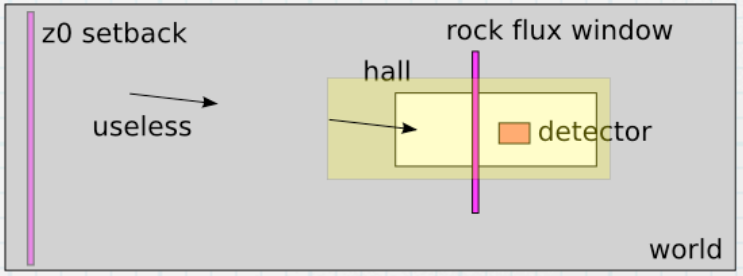
Choosing a Vertex "Outside the Box"

- When a "topvol" isn't set, GENIE considers the entire geometry
- GeomSelectorRockBox trims the volume to the hall + minimum safety + a size proportional to the neutrino energy
- Integrated into GENIEHelper, but not yet used for production

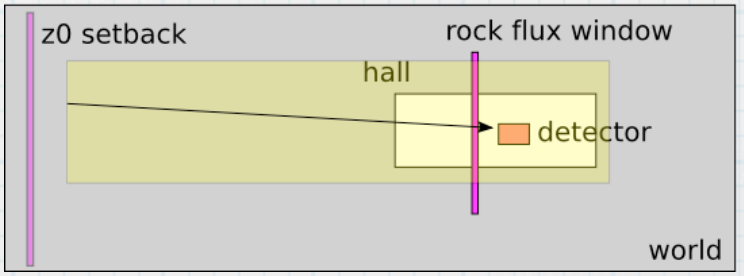
No GeomSelector



RockBox: 2 GeV

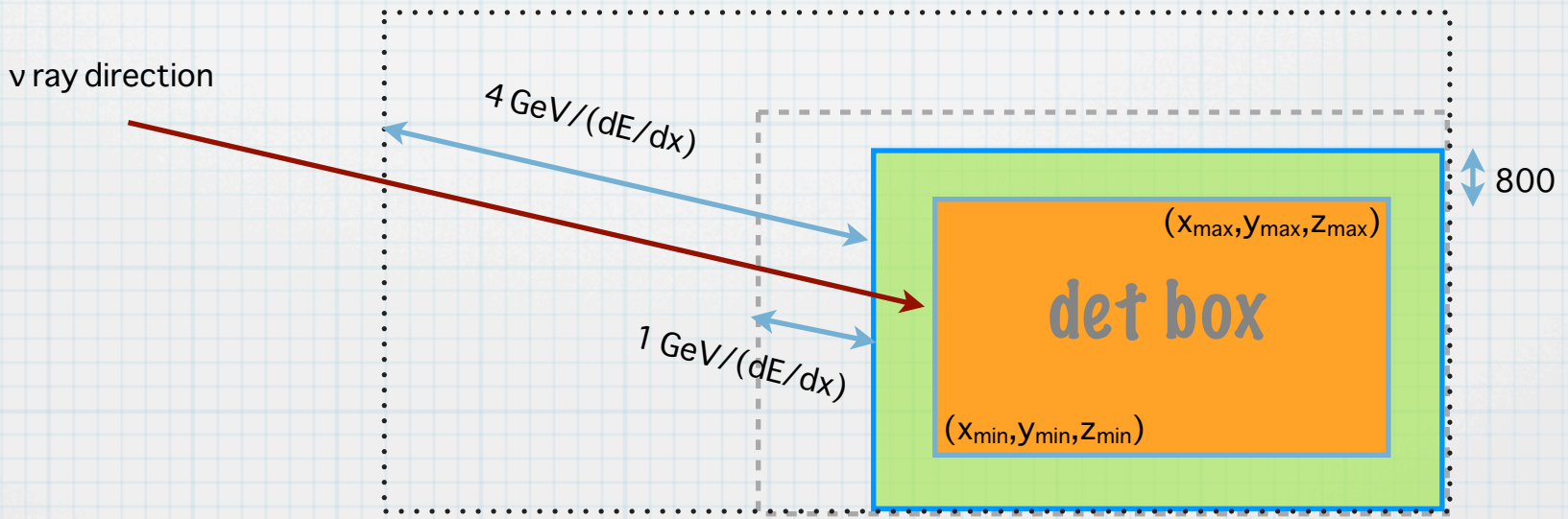


RockBox: 80 GeV

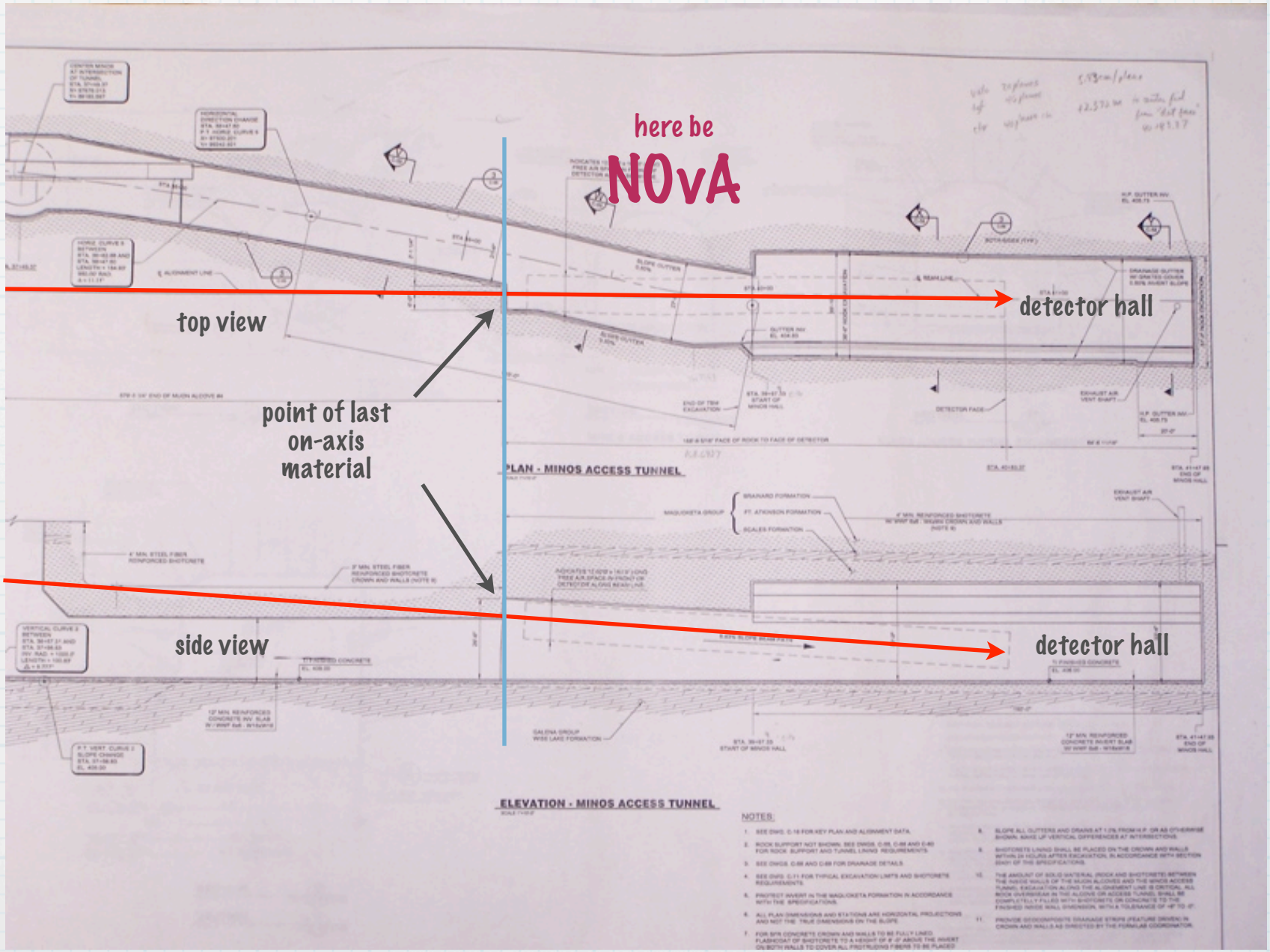


GeomVolSelectorRockBox

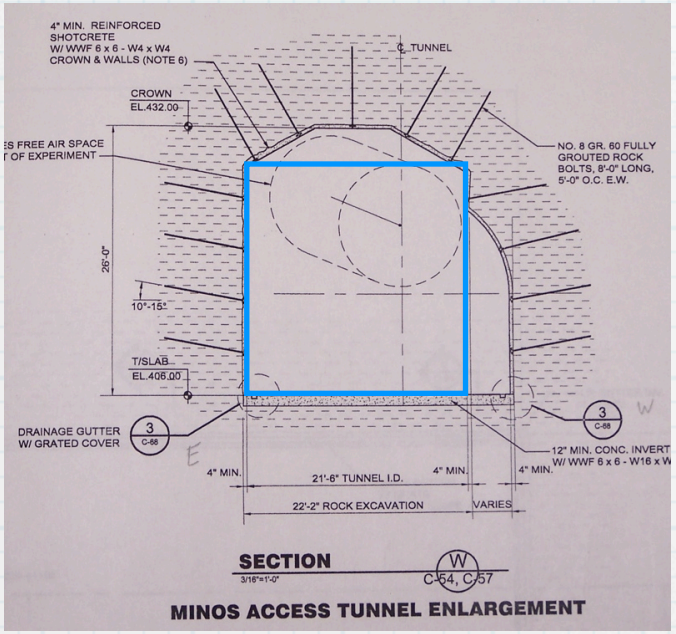
- GENIEHelper configuration for NOvA NearDet
  - physics.producers.generator.FiducialCut:
  - "rockbox:(-180,-180,-500)(180,180,1725),0,800,4.47e-3,1.10"
    - $(x_{min},y_{min},z_{min})(x_{max},y_{max},z_{max})$ = basic box size (geometry units)
    - 0 = include box interior (orange region), 1 = rock-only
    - 800 = minimum extent beyond box (geometry units, NOvA=cm)
    - 4.47e-3 = dE/dx (GeV/distance unit) in representative material
    - 1.10 = fudge factor for extending the box

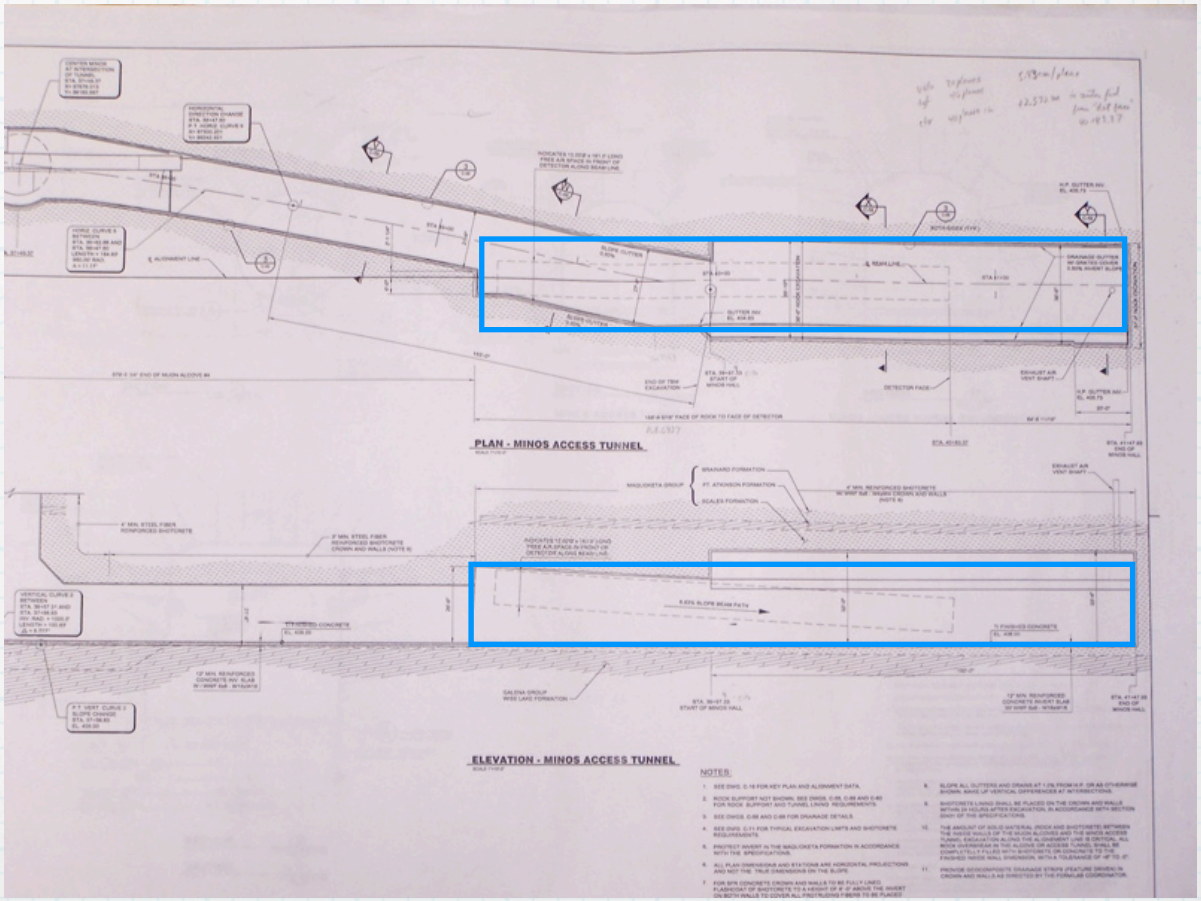


Tunnels/Caverns NOT a simple shapes



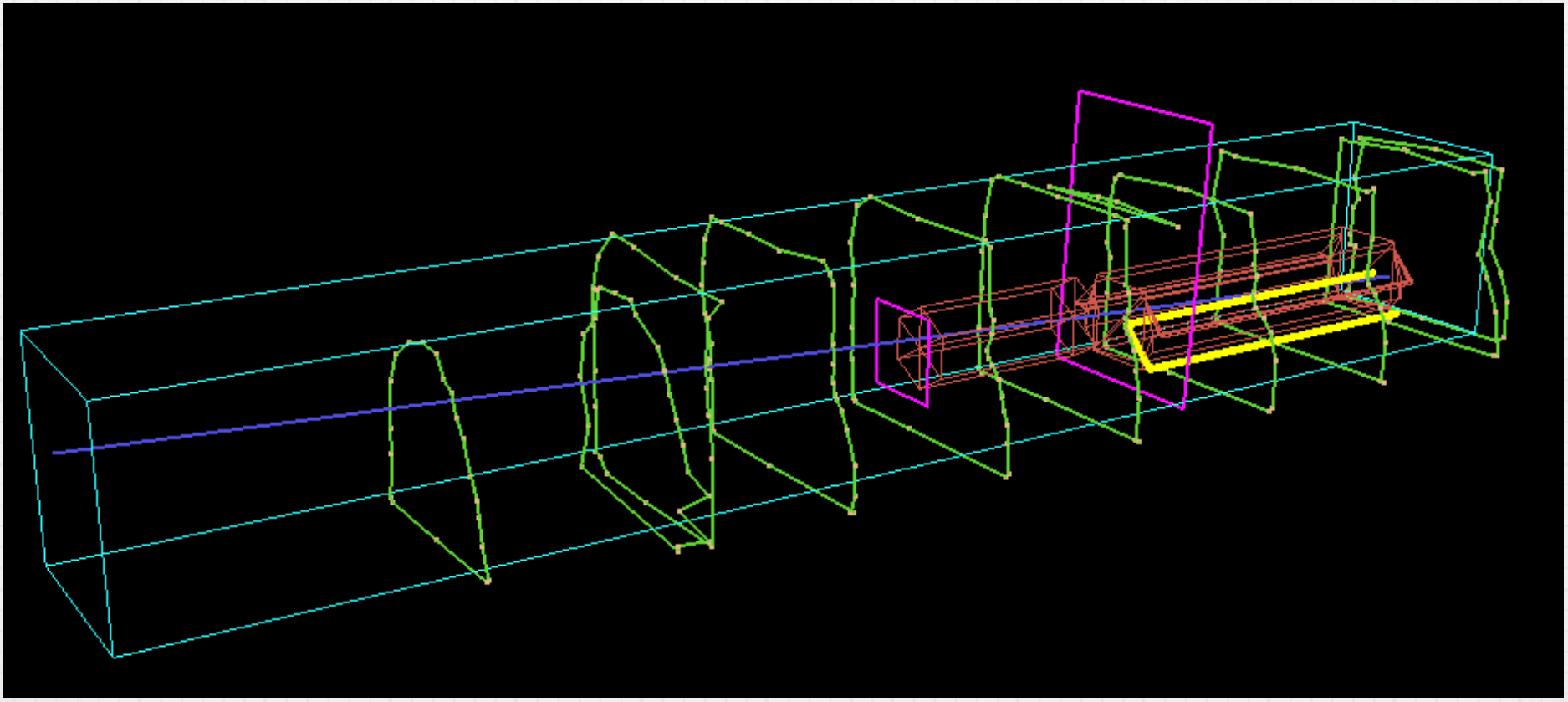
Simplified cavern





How did MINOS model it?

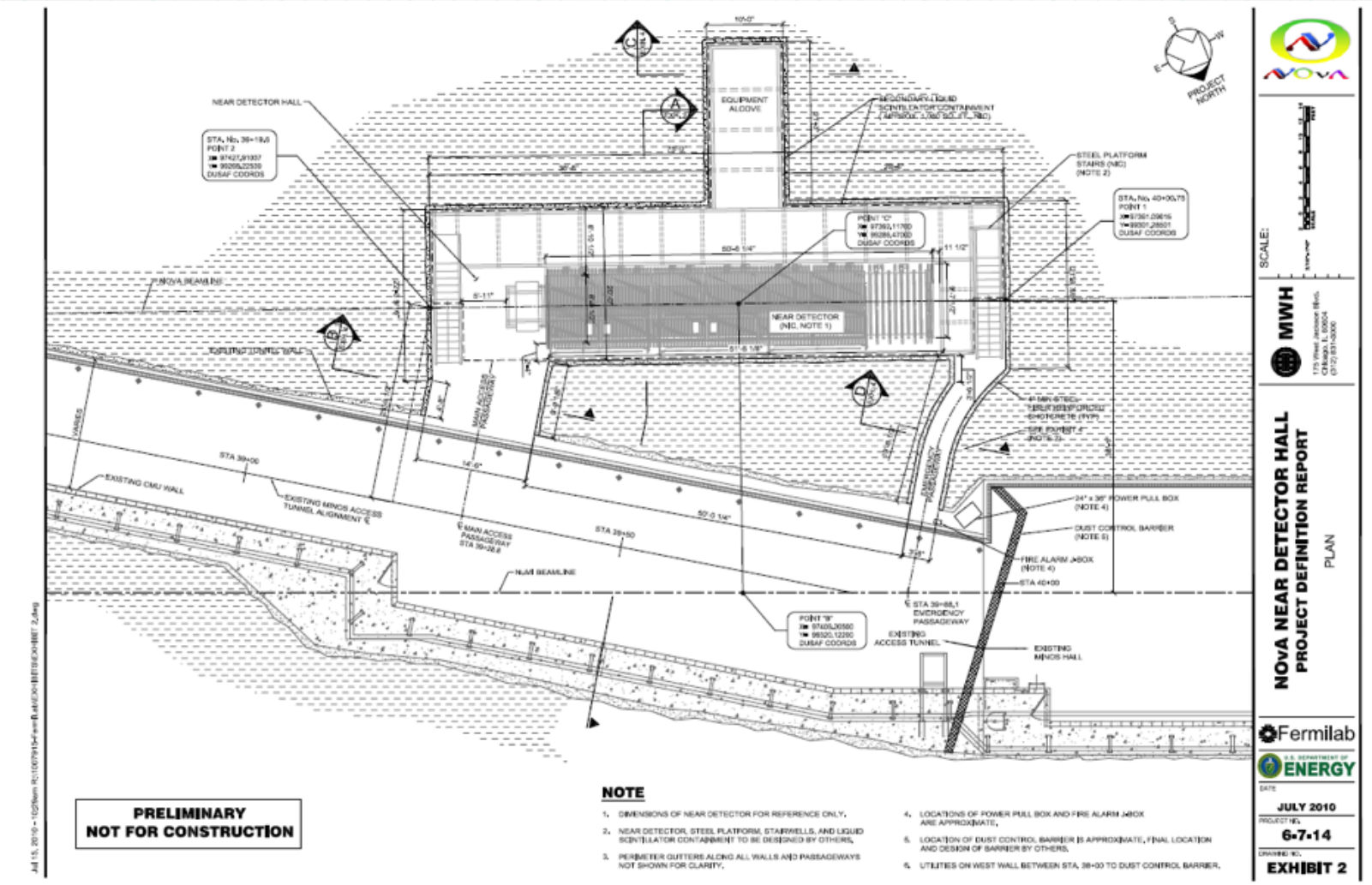
- MINOS Near Hall model is not very accurate
  - ...just a rectangular box



GMINOS "hall" | survey measurements | detector | flux window | beam centerline

NOvA Cavern

- NOvA plans (or at least one version thereof)

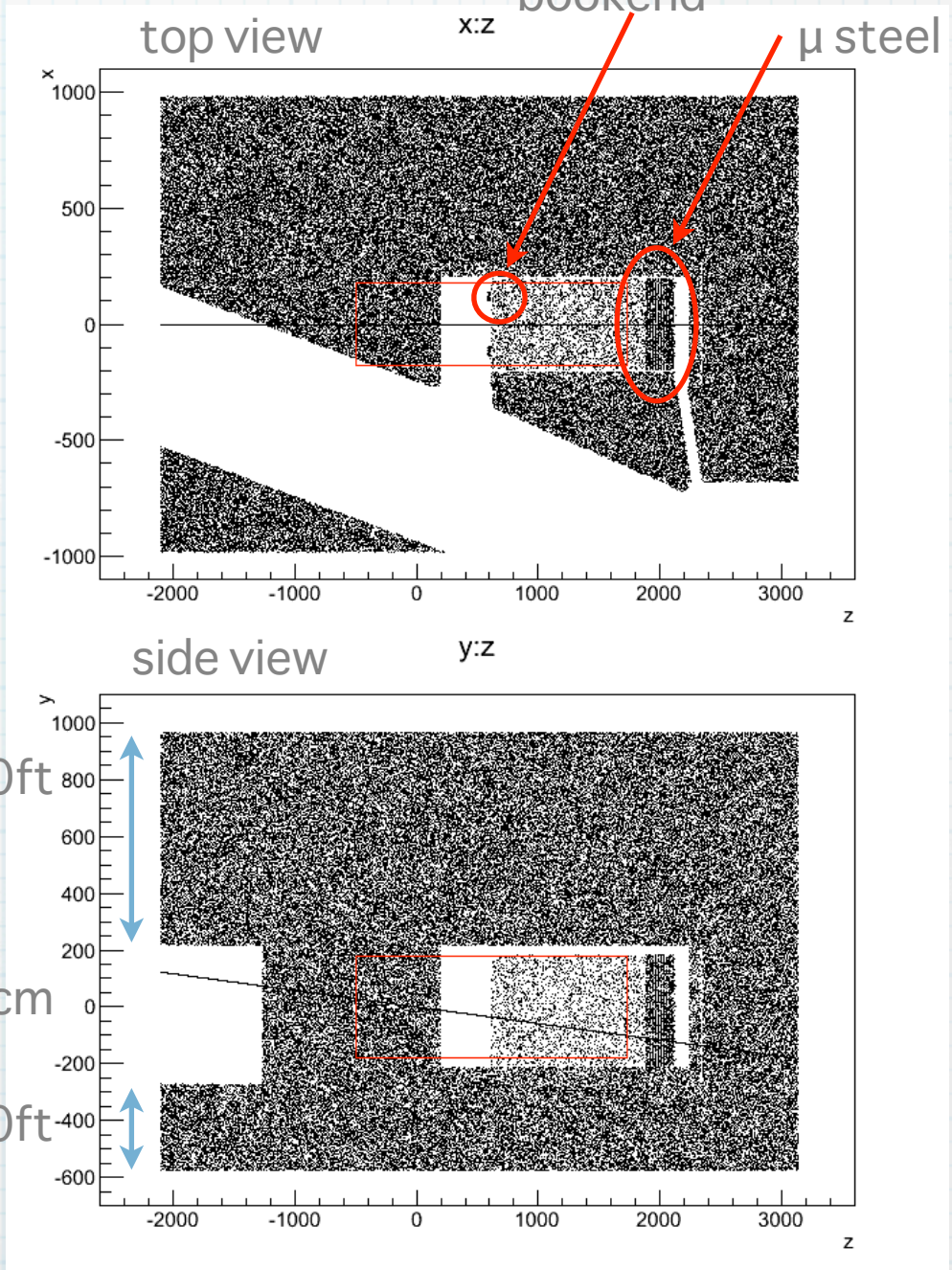


MC Tomography

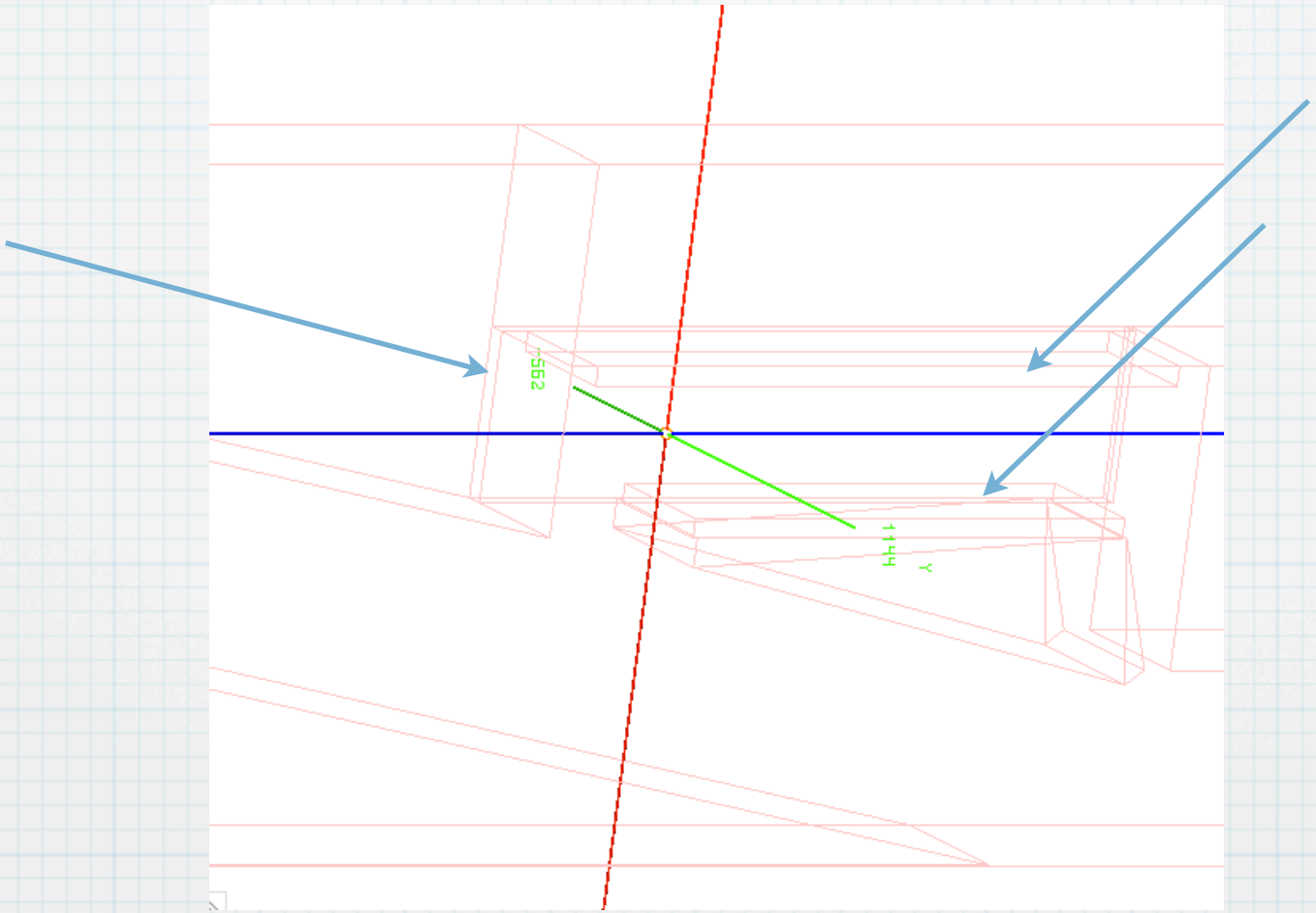
- Generate events with a fake flux
  - + shaped, w/ down slope
- rock model in the geometry is … odd
- world is 1000x detector dimensions
- rock base 10ft thick (304.8cm)
- rock top 30ft thick (914.4cm)

```
simb::MCTruth mcTruth = (*mcTruths)[itruth];
simb::MCNeutrino nu = mcTruth.GetNeutrino();
simb::MCParticle nupart = nu.Nu();
TLorentzVector vtx = nupart.Position();
```

- box should be ~5m upstream to just after last plane
- odd z offset of ~600 cm



Freaky



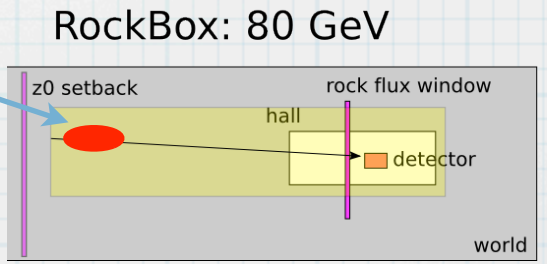
Rock Event Generation Issues

- Needs external info about box sizing
  - GENIEHelper currently doesn't know how to extract an appropriate box from the geometry
  - perhaps someday it could extract extent from volume name
- vDetEnclosure includes "rock"
  - this is how NOvA geometry is currently configured
  - bad for both detector-only and rock-only cases
    - for "detector-only" generation we get lots of events that are actually in this interior rock and not very useful
    - validation group has to impose external cuts when making plots because $\rho_{rock} >> \rho_{NOvA}$; many events are in this rock
- Test with large fudge factor to see if results change
  - should get no additional energy deposition
  - want to be conservative, but not wasteful of resources

Rock event considerations

- In the MINOS processing model, single events are independently propagated (via GEANT) to generate hits (energy depositions) after event generation.
  - GENIE must pick vertex before deciding interaction kinematics
- GEANT hooks are setup to skip propagation of particles deemed unlikely to reach the detector hall
  - This saves significant time!
- Events that contribute no energy to the active detector elements are dropped.

80 GeV high-y event might still have no particles that reach the detector

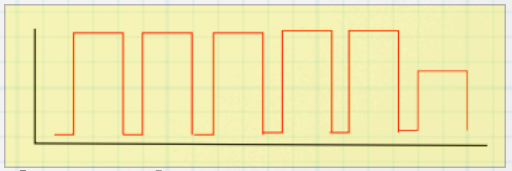


Two Overlay Approaches

- MINOS does overlays by independently generating individual “detector” and “rock” single events and performing overlaying as a separate processing step
  - After singles generation: calc events/POT
  - Rock events are shuffled and re-used (10% POTs generated)
- NOvA has plans to try to do it all in one.
- GENIE is more attuned to the first approach
  - need to stop after X protons-on-target for a spill; GENIE really designed to give you an event and tell you how many POTs you’ve used (total!)
  - Flexibility for re-overlaying with different intensity

How to overlay

- Collect events
  - MINOS: pull from input sample files
    - Poisson distribution - nDetPerSpill + nRockPerSnarl for a given intensity
    - single use of detector events, randomize pulling from rock files (reuse, except once)
  - NOvA: generate events until used X POTs
- Distribute events in time over spill interval according to intensity profile
  - offset truth info times (StdHep/HepMC)
  - also offset corresponding hit times, if already propagated in GEANT
  - if combined particle list, adjust parentage indices
  - add any event kinematics/flux records to list for spill
    - good to have mechanism tying kin/flux to particle list



Rethink Overlay Strategy?

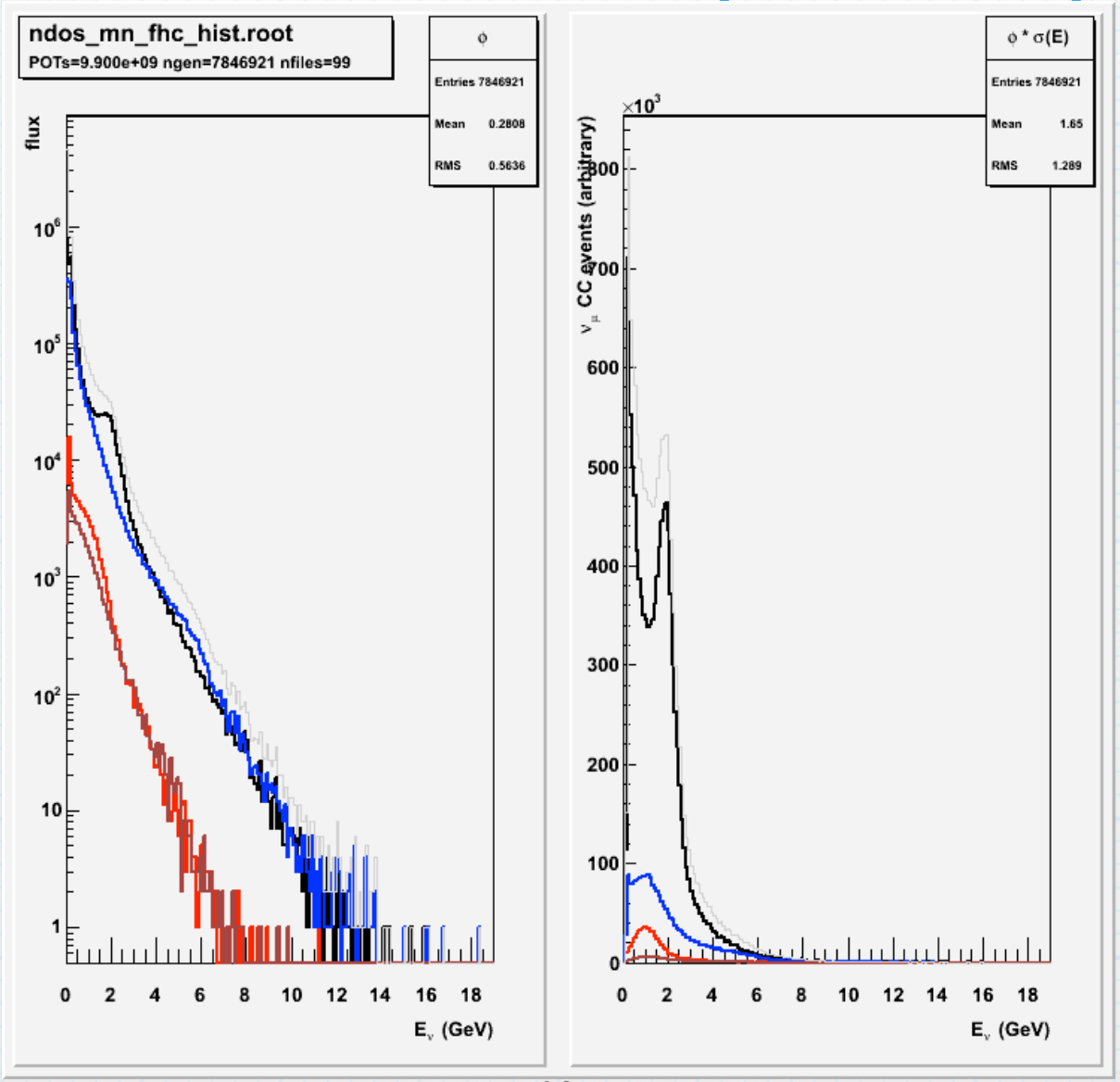
- Because there is no killing of rock events that contribute no actual energy to the detector these will tend to clutter up event list
  - Even if “neutrino” could have produced event that reached detector, depending on “y” it might not have … GENIE can only deal with the first condition.
- Talked to ART developers -- it is supports reading multiple files (mu2e does this)
- Are we going to use events w/ vertex in the rock for analysis, or just a nuisance factor?
  - for 2nd, reuse of events save compute power

Geant 4

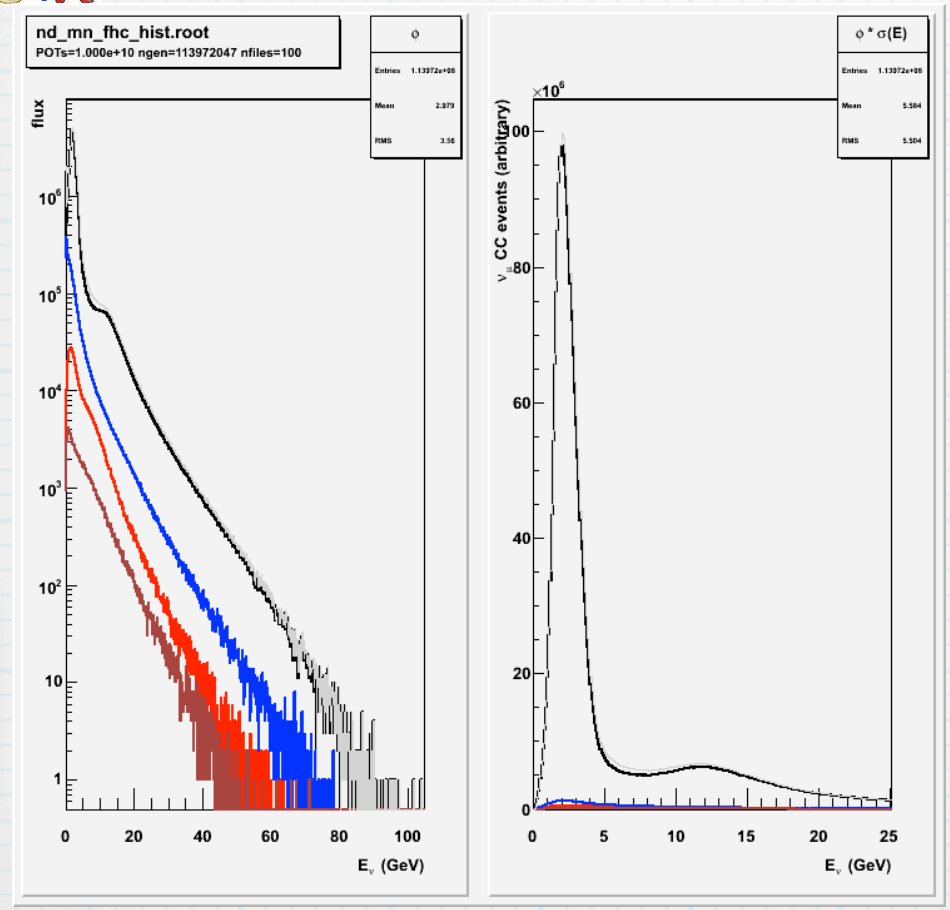
Dragons, it had to be dragons

- More stuff goes here

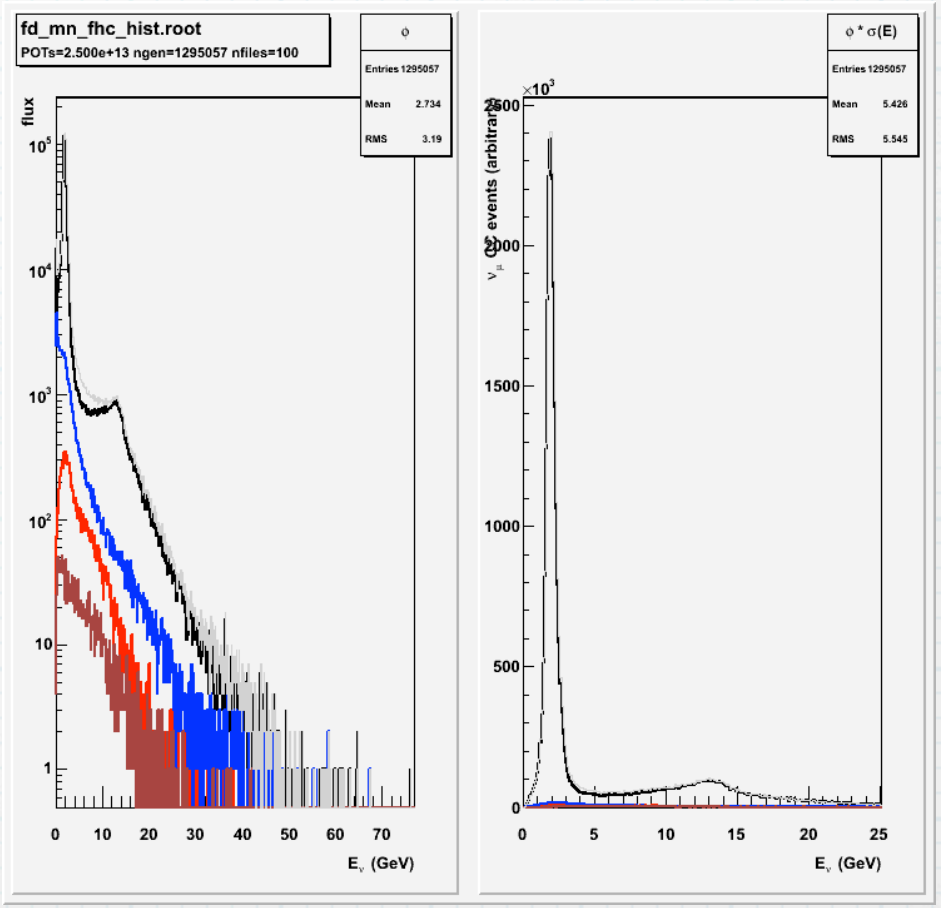
Flux/Event Energy Distribution (NDOS)



Flux/Event Energy Distribution



NearDet

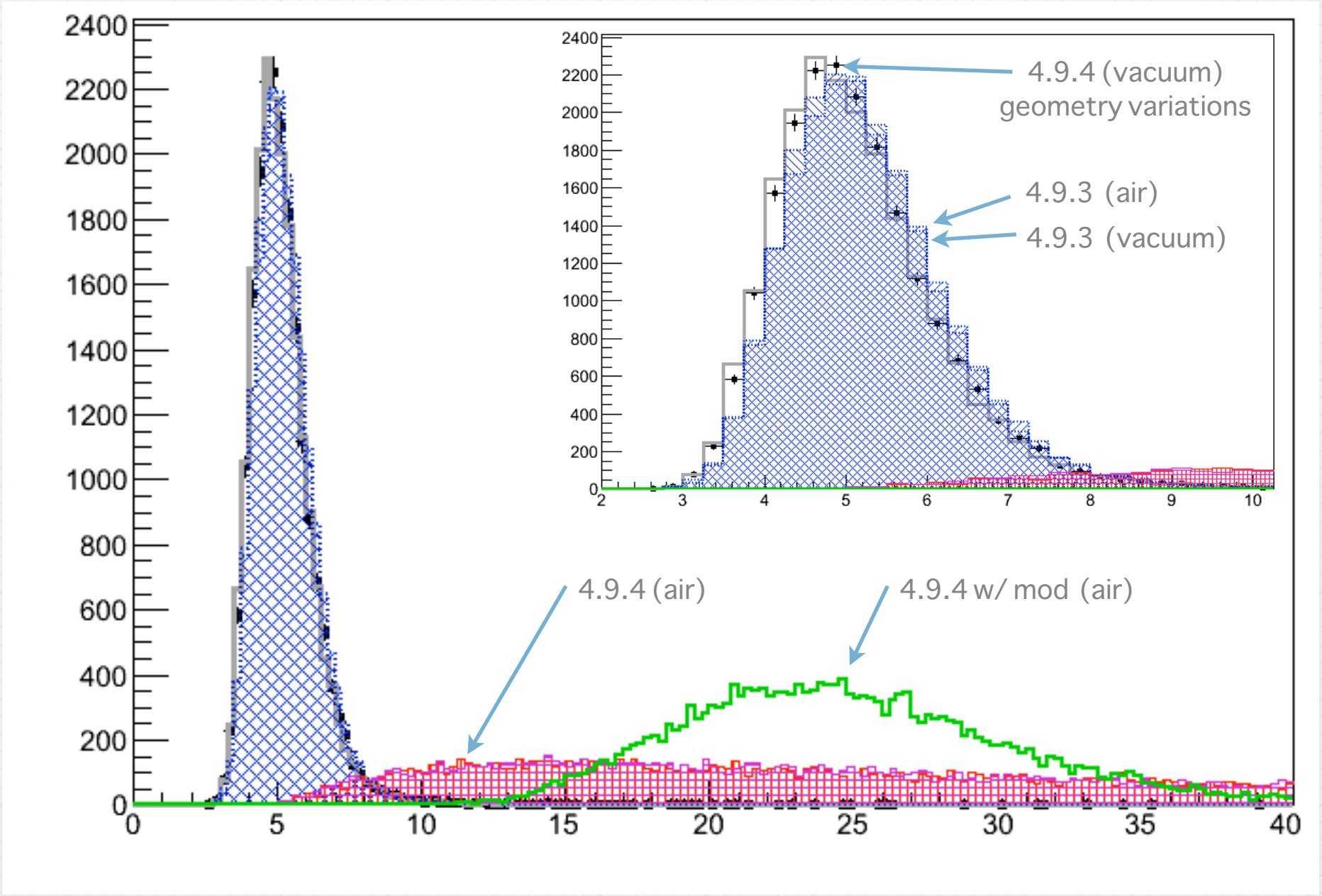


FarDet

Geant4 electron showers

- There must be a fundamental numeric instability in `SampleCosineTheta` that turns small `theta0` (mean angle?) into a chosen *cosθ* that is unreasonably far from 1
- Geant4 team sent a proposed fix
  - old: `if(theta0 < tausmall) return cth;`
  - new: `if(theta0*theta0 < tausmall) return cth;`
  - `theta0` is a mean scattering angle
  - `cth=1` and `tausmall = 1.0e-16` at this point
- I'm not convinced that this new variation on the cut does anything more than make the problem less frequent

Shower Width



Urban 2006 (cern-open-2006-077)

- Angular distribution

$$g(u) = p[qg_1(u) + (1-q)g_2(u)] + (1-p)g_3(u)$$

$$g_1(u) = C_1 e^{-a(1-u)} \qquad -1 \le u_0 \le u \le 1$$

$$g_2(u) = C_2 \frac{1}{(b-u)^d} \qquad -1 \le u \le u_0 \le 1$$

$$g_3(u) = C_3 \qquad -1 \le u \le 1$$

where $u = cos\theta$, $0 \le p, q \le 1$
g_i are simple functions normalized over the range $u \in [-1, 1]$

- for small `theta0` for small steps at high energies one physics intuition says to expect p=1, q=1
- not sure I see the left hand constraints in the code